

# White Paper

Report ID: 113064

Application Number: PF-50431-14

Project Director: Christina Cain

Institution: University of Colorado Museum

Reporting Period: 9/1/2014-9/30/2016

Report Due: 12/31/2016

Date Submitted: 12/29/2016



**National Endowment for the Humanities  
Sustaining Cultural Heritage Collections  
White Paper**

Grant Number: PF-50431-14

Project Title: Sustainable Microenvironment for Collections Storage

Project Director: Christina Cain, Anthropology Collections Manager

Grantee Institution: University of Colorado Museum of Natural History – Anthropology Section

Date Submitted: 12/30/2016

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## **Project Summary**

In 2013 the University of Colorado Museum of Natural History (CUMNH) received \$40,000 from the National Endowment for the Humanities Sustaining Cultural Heritage Collections Planning Grant to fund a team-developed program plan designed to sustainably microclimate and stabilize the environment of two storage spaces in the Museum facility. The Museum additionally received \$10,000 to implement one of the recommendations to come from the planning process.

The spaces that were the subject of this project house some of the most well-researched, valuable, and fragile artifacts in the Museum's anthropology collections. As a nationally renowned collection, these artifacts have been at the top of the Museum's preservation priorities for a number of years. Previous grants, fundraising efforts, preservation assessments, and creative solutions have been employed to ensure the safety of these pieces. However, the 79-year old building environment continues to be a challenge for conservation. While poor climate and fluctuations can cause mechanical damage to objects, the heat in the spaces also creates an enticing environment for museum pests that can destroy collections.

Previous planning efforts focused on solutions for the entire facility. These plans were ultimately not feasible to implement given the cost and energy usage required. A more sustainable plan with a goal of creating a microclimate was necessary. NEH SCHC funding was utilized to develop a program plan to improve the entire envelope of these two spaces and to take the steps to create a schematic design for a sustainable mechanical system.

CUMNH partnered with University facilities management and planning staff, electricians, Integrated Pest Management, and HVAC experts, as well as preservation environment experts from the Image Permanence Institute (IPI - Rochester Institute of Technology) to collaboratively plan a sustainable, feasible preservation environment focusing on two storage spaces within the larger museum building. Through meetings, tours, building reviews, and education, a design was created that takes into account resources available to the building, preservation standards, collections and staff needs, and sustainability.

## **Activities and Accomplishments**

Built in 1937, the Henderson building, which houses the anthropology collections, lacks temperature and humidity controls that would provide a sustainable preservation environment that is up to museum standards. Radically changing temperature and relative humidity from season to season puts the fragile collections at risk for deterioration and damage and warmer summer temperatures provide a safe and inviting environment for pests. Years of monitoring of both environment and pests show a direct correlation with a rise in pest activity in the summer months when the temperature is high and the RH increases due to outside conditions as well as the use of an evaporative cooler in the building. Because addressing the entire building is not feasible given funding and other resources, focus turned to seeing what could be done for a small portion of the space. The goal of this project was to design microclimates for storage of museum artifacts within approximately 3,400 square feet of the existing building. Additionally, and outside the grant activities, the University funded an effort to seal all exposed areas of two of the spaces in order to limit pest infiltration from the outside, and a project to insulate the ceiling of the top floor of the building, which includes the third and fourth floor spaces subject to this project. Lastly, additional funding from NEH was approved for a small implementation project to come of this planning. That project would include the insulation and drywall work for one of the spaces that had the most exposure to the outside conditions.

## ***Microclimate Design and Planning***

Mechanical engineers met with museum staff, CU facilities management staff, and CU campus architects in addition to representatives from the Image Permanence Institute (IPI) in person and over the phone

to review current systems and examine relevant storage spaces, building interiors, exteriors and vulnerabilities. IPI provided background information on ideal preservation environments and sustainability practices for heating, ventilation, and air conditioning equipment and couched all of these recommendations into the Colorado environment. This was truly a collaboration between preservation experts, both with IPI and the museum staff, and CU facilities and campus experts. Throughout the planning process, engineer Don Reaville consulted with museum staff and with IPI. His findings and final schematic design (Appendix A) represent this collaboration, integrating priorities in preservation, sustainability, and feasibility. The following discussion summarizes findings and final planning results.

The existing HVAC systems in the museum building are not currently suited for long term preservation of museum materials. The objects in need of dedicated storage within this building consist mostly of Native American textiles and pottery, largely from the Southwest US. The materials have been exposed to relatively dry climate conditions for most of their lives until collected and stored within the current facility. The HVAC systems within the museum building utilize direct evaporative cooling to maintain cooler temperature conditions in the summer months. This type of system consequently results in what can be relatively humid conditions in summer compared to the natural states that the artifact materials were exposed to previously. Conversely, the evaporative unit is not used in the winter, resulting in a drastic and steep decline in relative humidity levels.

Though many museum institutions across the country maintain fairly consistent ideas about the best standards for ideal preservation conditions for different types of artifact materials (most often 68-72° F and 45-55% RH), current research from the Image Permanence Institute suggests taking the object history, materials, geographic location, and sustainability practices into account when developing environmental systems and set points. What would be less than conventionally acceptable conditions would be more appropriate for the materials housed within the collection at the University of Colorado Boulder. The corresponding deductions indicate that maintaining long term humidity conditions for materials that vary significantly from their long term natural state could indeed be harmful, causing further mechanical damage to the materials and reducing their overall lifespan.

Recommended conditions are those which maintain the materials within their elastic limits, thus preventing mechanical damage to the materials themselves. Materials vary in what these elastic limits might be, but the generally accepted safe range of humidity level is 35% to 50% Relative Humidity (RH), with the outside limits being 30% and 55%. The majority of materials, including those textiles and pottery known to be included in the museum's collection, take a relatively long period to come to equilibrium with the space conditions with regard to the amount of moisture absorbed from or released to the surrounding environment. Given this relatively slow rate of change in the materials moisture content, rapid changes in space RH can occur with virtually no concern to the preservation of the materials as long as the RH conditions are adequately maintained within the elastic limits of the materials. Tight tolerances or limited rates of change for space humidity are not necessary, and providing specialized equipment to maintain what might be referred to as 'mission critical' space conditions would be excessive and unnecessarily expensive.

The story is similar for the case of temperature, though most materials will come to equilibrium at a much quicker rate when the material temperature and the space temperature are not of extreme variances (i.e. 80° F materials suddenly exposed to a 35° F environment is notably more extreme than 65° F materials somewhat suddenly being housed in a 60° or 70° condition). Again this relationship between materials and environment aligns with the suggestion above that 'mission critical' level temperature control with extremely tight tolerances and very limited rates of change is not necessary.

The ideal temperature conditions for materials preservation generally abides by the premise that cooler/colder is better. The debate for selecting an appropriate storage temperature relates more to

human occupants and their use of the space. The storage areas for the collections at the University of Colorado are also used as work spaces. Maintaining comfortable or acceptable working conditions is in direct conflict with maintaining ideal storage conditions. For times when the space will be or has the potential to be occupied, a suggested space temperature would be within the range of 60-70°F, but likely more specifically in the 65-68°F range. Maintaining stable temperature for occupied conditions will suit human comfort, but allowing for drift in that space temperature to lower values in the winter time would be quite acceptable.

The goal of this plan and design is to create a 'microclimate' within the building, that will allow for significantly improved preservation conditions for the collection. That process will involve dramatic improvements in the insulation, vapor barriers, and air barriers for these areas to create spaces that are much more immune to changes in or conditions of the environment surrounding the controlled microclimate.

Given the aforementioned considerations, providing a climate control HVAC system for these storage areas should involve readily commercially available systems of reasonable expense for quality and long-lasting products. Some designers and even curators might consider a Computer Room type AC unit, with the knowledge and understanding that this is a high quality and mission critical type of system. While these characteristics are indeed inherent in these systems, the level of precise temperature and humidity control is not necessary.

Systems that utilize DX cooling (Direct Expansion, similar to those found in most home and many commercial AC systems) are generally less capable of maintaining space temperature and humidity conditions that are outside of the ideal target ranges for human occupancy. Stated another way, maintaining conditions for preservation (in the 50-65° F and 35-55% RH range) rather than at high human space comfort conditions (72-78° F even at comparable relative humidities) is much more reliably and effectively achieved with a chilled water type system rather than a DX system. DX equipment is generally cheaper to purchase, and cheaper to maintain, but operational energy consumption costs are typically greater than with chilled water systems. Additionally, the life expectancy of chilled water systems is appreciably improved over that of DX systems if well-maintained (maintenance being responsible for improved life-span with any equipment), on the order of 20-30 years for chilled water systems as opposed to 12-20 years for DX systems. Given these considerations, chilled water type systems are the advisable choice for an effective preservation environment.

Cooling and heating loads have been estimated based on the assumption that new insulation and vapor barriers will be provided to maintain an effectively insulated envelope for these storage areas. It is expected that all existing windows within the project areas will be sealed effectively, covered on the interior to prevent introduction of sunlight, and insulated.

Humidification source will be evaluated during the detailed design phase, but each fogging, dedicated local steam generator, and campus steam will be considered and evaluated for appropriate selection with CU Facilities.

Heating source for the AHU will be considered in more detail during further design efforts, in collaborative review with CU facilities. The heating needs for this space will be minimal compared to other building comfort heating systems with no man-doors to the exterior, no exposed windows, a well-insulated and air-tight (bug-proof) envelope, minimal outside air, and a maximum occupied space temperature of 65-68° F during winter.

The anticipated approach to heating controls will involve only operating heating systems during occupied times. Given the thermal mass of the existing building, and the expected integrity of the space insulation envelope, it is expected that drift temperatures during unoccupied periods will be maintained

well in excess of freezing. An expected minimum drift temperature during unoccupied times is suggested to be 50° F. Given these operational parameters and expectations, heating consumption should be relatively minimal and electric heat may prove a viable choice if acceptable to CU facilities. Additionally, electric heat would indeed be the least expensive and simplest approach.

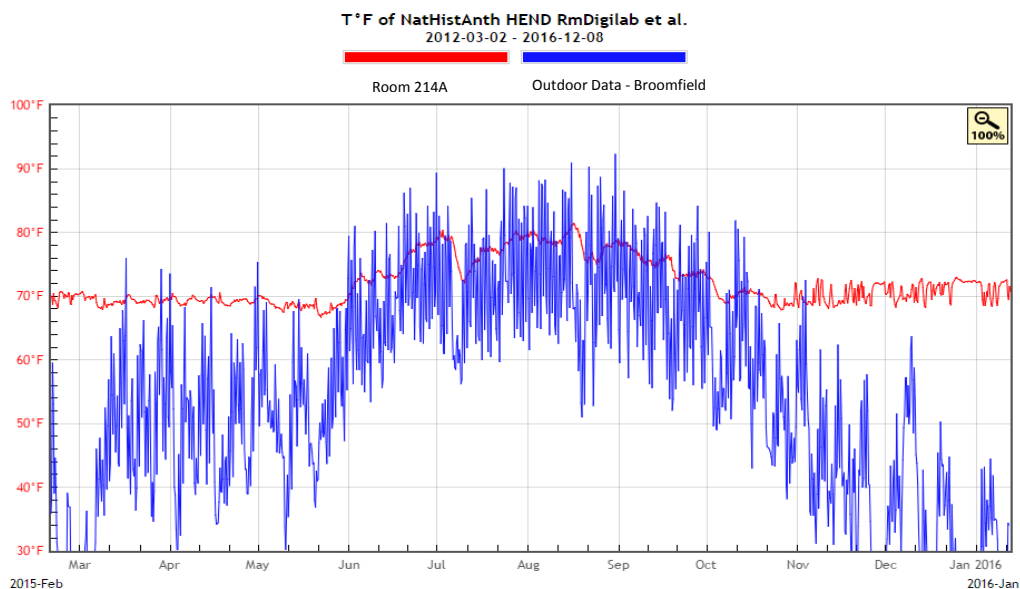
Based on discussions with museum staff, as well as consultants with the Image Permanence Institute, the targeted indoor conditions for temperature and humidity are as follows:

Relative humidity – Space RH will be maintained at all times between 35 and 50%. Relative humidity conditions will be allowed to float between these two points with humidification initiated to maintain a minimum of 35% in the space, and dehumidification via mechanical cooling initiated to maintain a maximum of 50%.

Temperature – Space temperature conditions will be maintained between a minimum of 50° F in the space during unoccupied conditions, and a maximum of 68° F during occupied conditions for occupant comfort. Unoccupied maximum temperatures will be maintained at 65° F, for more ideal preservation conditions.

### **Implementation Project**

The implementation portion of this project took into consideration the general envelope issues for these spaces. Improving insulation and sealing out potential pest infiltration locations, which also allow in outdoor air, was the top priority. Due to budget and based on statistics for pest activity and environmental data, the small space (room 214A) off of the second floor room (214) was chosen. This space was added onto the building in 2010 and has three exterior walls. The exposure to the three exterior walls, which face east, south, and west, along with passive steam heat, a small dedicated electrical heater in the winter and evaporative cooling coming only passively from room 214 in the summer means summer temperatures are highly reactive and correspond to the outdoor environment.



This space also sees a lot of pest activity during the fall season when box elder bugs and conifer seed bugs are migrating and has a lot of spiders year round. The hope was that insulating and adding sheetrock to the walls will improve the envelope, doing some work to stabilize the temperature as well as keeping the pests at bay.



Before: Former Exterior Wall Meets 2010 Addition



During Construction: East Wall Preparation of Insulation



After: East Wall New Sheetrock Covers Insulation

While the ceiling in this space was insulated when built, the walls were cinderblock and contained no insulation. The exterior walls were outfitted with R13 EcoTouch® Pink® Fiberglas™ Insulation and gypsum sheetrock® panels. Finishing this space with insulation and drywall fit the budget of the implementation project and provided a good test case for envelope improvement. Monitoring of the space for pests and environmental fluctuation will be addressed in the Evaluation section below.

### ***3<sup>rd</sup> Floor Insulation Project***

Upgrade plans for the Henderson storage envelope included full insulation of the ceiling in the third floor rooms and the fourth floor tower room, all directly under the roof. Originally this work was funded by CU and scheduled to occur prior to the start of this grant project. It was our hope to monitor spaces and develop plans that would extend beyond the insulation, as we know this is the most basic upgrade that needs to take place. However, due to changing senior level facilities staff and funding allocation priorities, the project was postponed indefinitely and did not take place during the grant period. This project is now back on the schedule for the summer of 2017.

### ***2<sup>nd</sup> Floor Integrated Pest Management Sealing Project***

Museum staff have worked with the office of Integrated Pest Management (IPM) on campus for over a decade. Henderson has seen a number of pest issues over the years and the IPM department has been a constant partner and supporter of improving the building and protecting the objects housed here. Through consultation on ways to better deal with the pest issues at the room level, IPM brought in an outside contractor to evaluate the second floor spaces relevant to this grant. These rooms consistently have a population of odd beetle larvae and also have seasonal invaders, such as box elder bugs. Because of this, the room is not appropriate to house our proteinaceous materials, though it has the most space in the building for this type of storage. To attempt to improve the pest situation, it was determined that one course of action would be to caulk and seal all baseboards, add door sweeps, and caulk closed the windows which had failing gaskets. This work was funded by the IPM department and carried out in May 2015. More information on this evaluation and results thus far can be found in the Evaluation section.

## **Evaluation**

### ***Schematic Design***

Throughout the design process, the mechanical engineer Don Reaville with Smith Seckman Reid, Inc. received recommendations from IPI with regards to specs, sustainable options, and best environment set points to attempt to achieve. Recommendations of the outside mechanical engineer were discussed

along the way with CU facilities management and much research was done to ensure the building, electrical systems, and campus infrastructure were capable of handling the proposed design. This collaboration resulted in an integrated plan that makes some compromises but still allows for a much improved preservation environment.

The final schematic design package produced by Don Reaville and SSR, Inc. was submitted to the building department on campus to evaluate for code verification and the estimate that was provided by SSR was thoroughly reviewed and critiqued. The lead reviewer for CU was Jacob Lee, mechanical engineer. While there will always be tweaks to any design as it goes beyond the schematic phase, the package has been fully vetted by CU and approved.

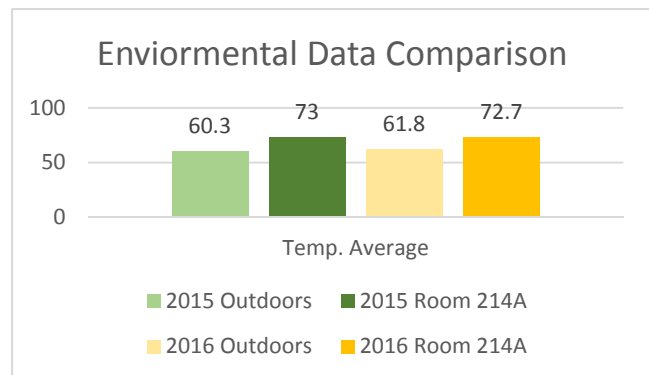
### **Implementation Project**

This project was completed in May of 2016. With the long term goals of the implementation project being the envelope improvement to help stabilize the environment and mitigate pest issues, monitoring of the spaces is critical to evaluation. Monitoring for pests has been a normal part of our procedures since the room was added onto the building in 2010. Monitoring includes sticky traps with general food pheromones. Traps are checked monthly with insect species and numbers recorded and evaluated.

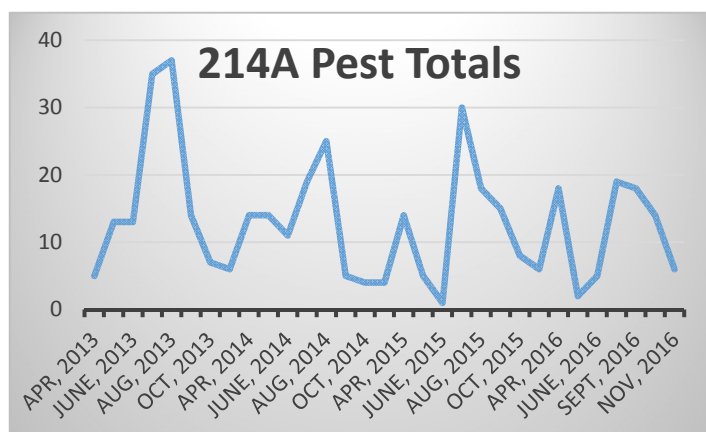
Environmental monitoring began in the space in January of 2015 as a part of this project. The room contains one PEM2 datalogger. Data is taken once a month and uploaded to IPI's eClimateNotebook software. Graphs and metrics are produced from that data to better understand trends within the room.

Data was reviewed for both pests (four years' worth) and environment (two years) for the months after the implementation project until now (May through November 2016).

Evaluation of climate improvement was difficult given only two years of data. Other facts that must be taken into account include an evaporative cooler shutdown, due to a maintenance issue, in July 2016 that lasted for several weeks. In theory, this shut down should have caused a higher average temperature and potentially lower average RH for the building. Data comparisons between the relevant months from 2015 and 2016, however, show that while the average outdoor temperature was 1.5 degrees higher in 2016 than 2015, the indoor average temperature was .3 degrees cooler. Could this mean that the improvements are insulating the room, even if slightly? It is possible, but far more data is required to come to any conclusions.



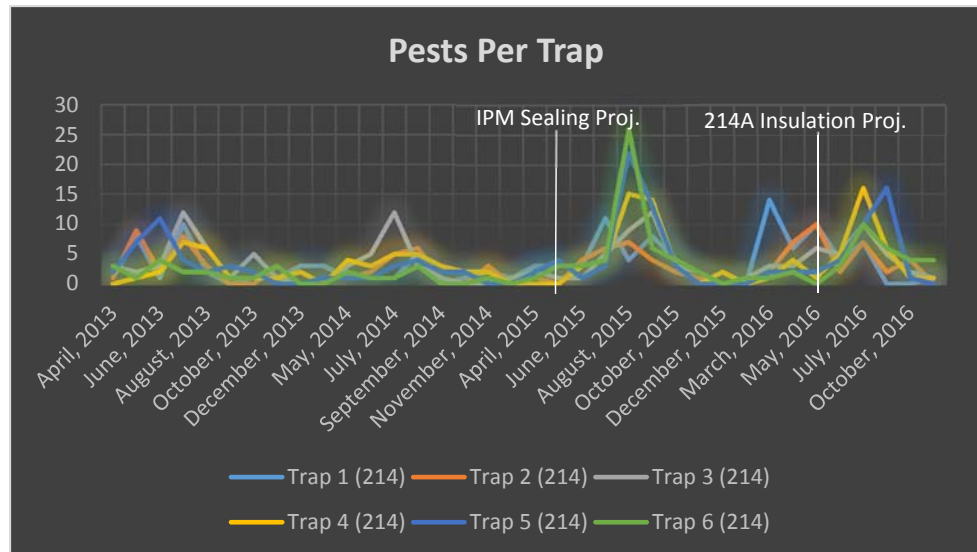
For pests, we evaluated the total number of insects found in the space over the relevant months from the implementation project until now and compared data from the same months from the last four years. Paying particular attention to the summer peaks, when pests are the most plentiful, we do see a lower number in total insects than the previous four years. While this could hint at success, there is not yet enough long-term data to draw any conclusions about the effectiveness of the



insulation barrier to pest activity. Continued monitoring will show more conclusive data from which to draw conclusions.

### **2<sup>nd</sup> Floor Integrated Pest Management Sealing Project**

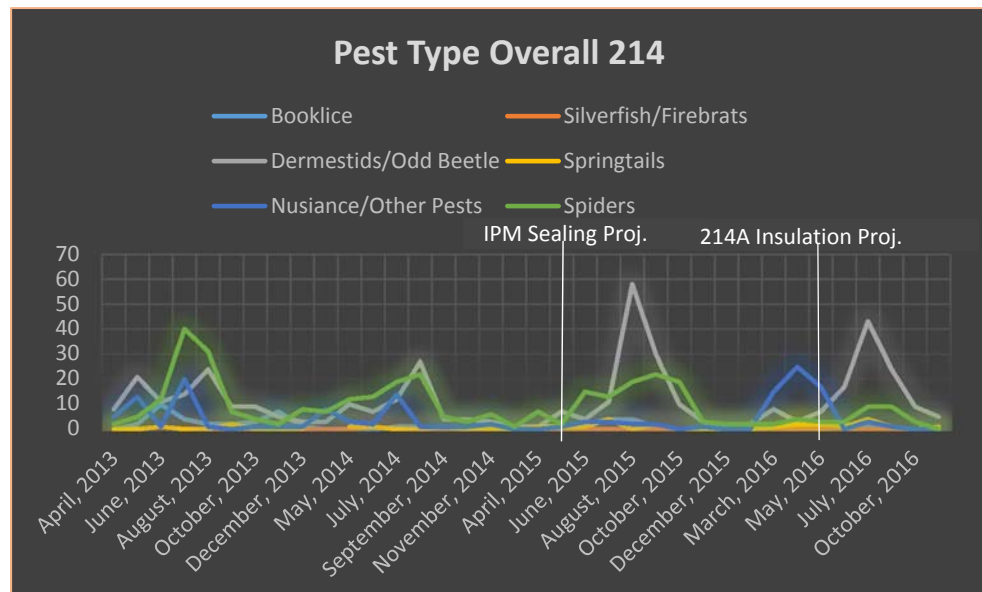
This project took place in May of 2015. Monitoring for pests is much the same as for room 214A. When examining data for the last two years, it appears overall pest numbers have gone down for most traps. However, when we further examined the last four years, numbers actually rose in 2015 and then came back down some in 2016. Is this a failure of the sealing project in some way? Additional study was required.



When we further examined the types of pests we were finding and those that increased in number, we find odd beetle larvae and clover mites are the only pests that increased, with all others decreasing.

Clover mites are a seasonal pest that come in in the spring with the wetter weather.

They are nearly microscopic so it is possible they are still capable of entering the room even after the mitigation. The odd beetle larvae likewise are very small. We theorize that an active population of the larvae live in the room and are not necessarily coming in from the outside. A lesson learned is that we must address the pest population already within the room in addition to enhancing the envelope security. While traps showed a decrease in total pests for the last year, the overall effect is still unknown without longer-term monitoring and addressing of the interior infestation.



## Continuation of the Project

For years, the director of the Museum has been working with the University to improve storage of all of the objects and specimens in every section of the museum. With the University under a new building moratorium, it is likely the collections will wait over a decade for any large-scale solution. This makes the design produced here all the more essential as it is obvious there will be no imminent relief for the most delicate collections. This plan will be reviewed again with the director of the Museum who is looking for ideas to send to negotiate with the University for upgrading the preservation environment in our current spaces. The timing is right to receive University support and providing them with a fully vetted design can only assist in the process.

## Long Term Impact

The long-term impacts of this design process apply to both the CU collections and the larger museum community. If implemented, museum collections will be protected for generations longer than the current environment would allow. The current average temperature and humidity translated into Time-Weighted Preservation Index<sup>1</sup> shows a TWPI for room 214 of 49 and a range in room 306 from 47-51.

NatHistAnth HEND Rm214 AHU-HENDevap

Risk Summary		Preservation Metrics		Data Overview	
Natural Aging	OK	TWPI	49	Start	2013-04-01
Mold Risk	GOOD	MRF	0	End	2016-12-01
Metal Corrosion	OK	%EMC Max	9.1	T°F Mean	71.2
Mechanical Damage	RISK	%EMC Min	3.7	%RH Mean	33
		%DC Max	1.5	DP°F Mean	38.8

NatHistAnth HEND Rm306 AHU-HENDevap

Risk Summary		Preservation Metrics		Data Overview	
Natural Aging	OK	TWPI	47	Start	2013-04-01
Mold Risk	GOOD	MRF	0	End	2016-12-01
Metal Corrosion	OK	%EMC Max	9.1	T°F Mean	72.5
Mechanical Damage	RISK	%EMC Min	3.3	%RH Mean	31
		%DC Max	1.61	DP°F Mean	38.6

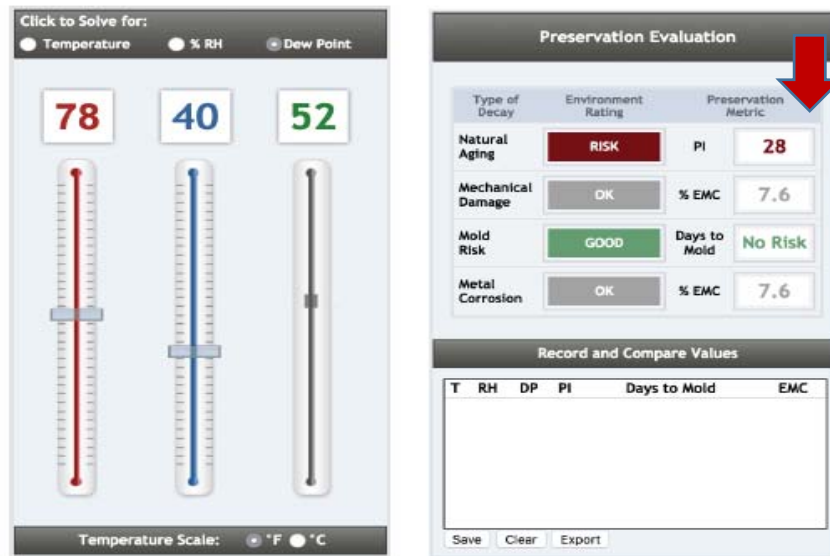
NatHistAnth HEND Rm306-2

Risk Summary		Preservation Metrics		Data Overview	
Natural Aging	OK	TWPI	51	Start	2014-12-17
Mold Risk	GOOD	MRF	0	End	2016-12-01
Metal Corrosion	OK	%EMC Max	8.8	T°F Mean	72
Mechanical Damage	RISK	%EMC Min	2.9	%RH Mean	30
		%DC Max	1.65	DP°F Mean	37

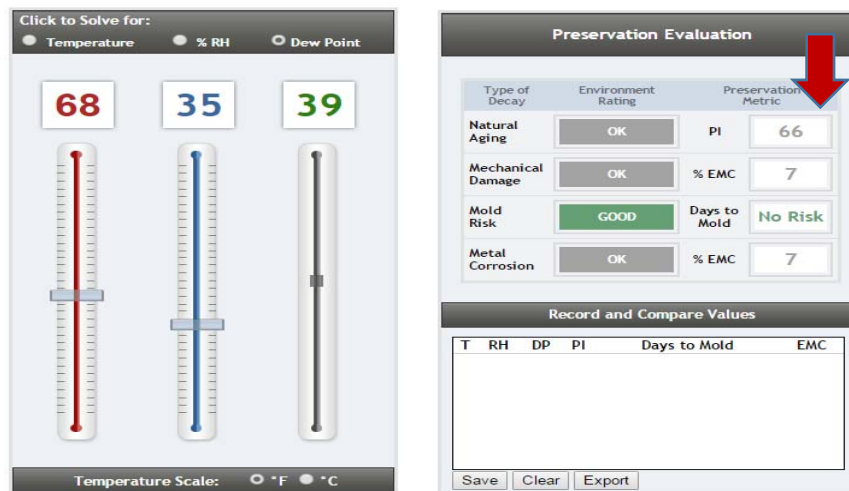
NatHistAnth HEND Rm306-3

Risk Summary		Preservation Metrics		Data Overview	
Natural Aging	OK	TWPI	49	Start	2014-12-17
Mold Risk	GOOD	MRF	0	End	2016-12-01
Metal Corrosion	OK	%EMC Max	9.3	T°F Mean	72
Mechanical Damage	RISK	%EMC Min	1.8	%RH Mean	32
		%DC Max	2.1	DP°F Mean	37.4

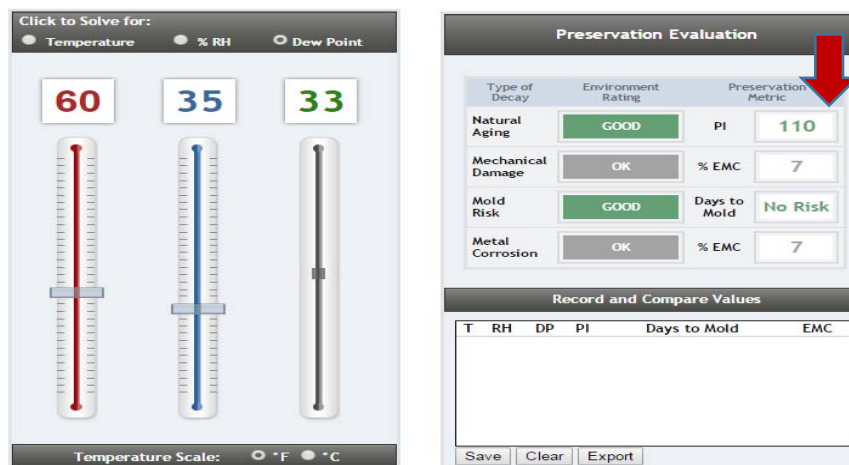
Current average summer conditions show a preservation index<sup>ii</sup> of only 28.



With new recommended and achievable set points that can be produced with the designed equipment, we can reach a preservation index of 66 in summer and 110 in the winter.



Summer Conditions



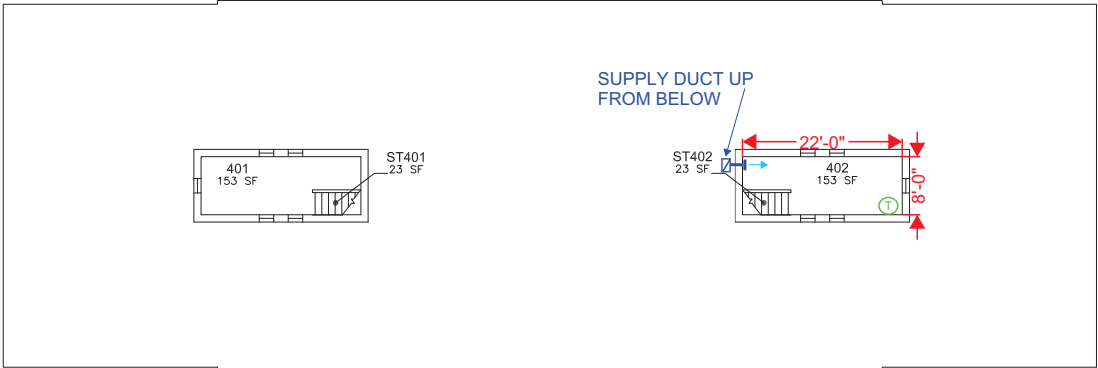
Winter Conditions

For the wider museum community, we are hopeful that dissemination of these collaborative methodologies and results will encourage a more holistic approach to preservation environment planning. While research on new standards and an elastic range approach to temperature and humidity set points has been around for decades, museums seem to be slow to catch on to a change in the old standard of 68°F and 50% RH. In fact, for most art and artifacts in most regions of the U.S., this standard is not only a challenge to achieve, but it may be detrimental to the preservation of the objects.

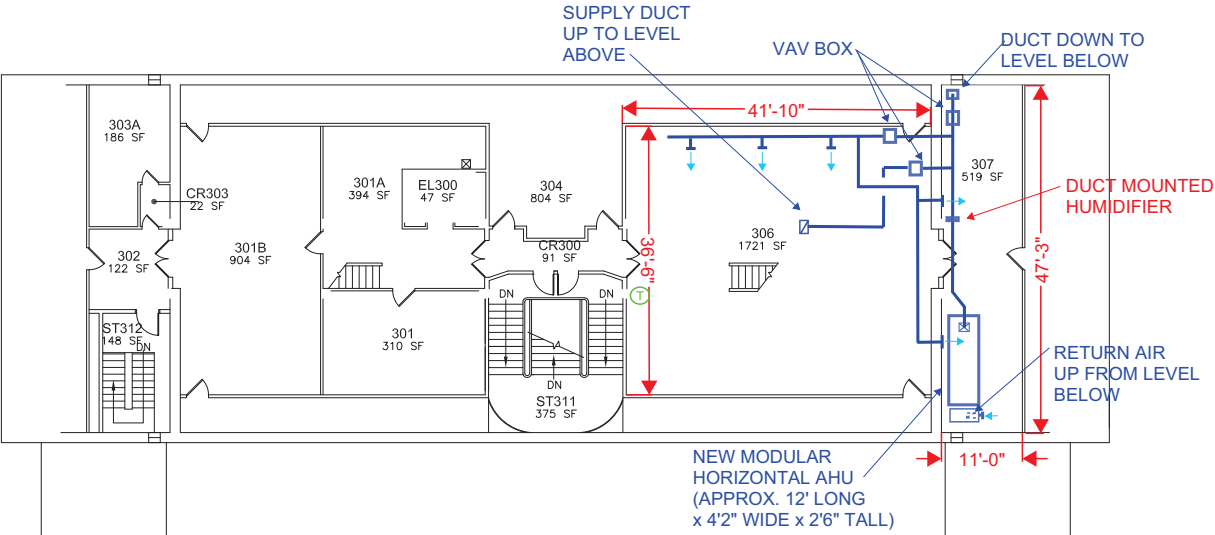
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<sup>i</sup> TWPI is a metric developed by IPI that condenses a period of changing temperature and RH conditions into one value (expressed in years) by averaging how much each interval of time contributes to the decay rate of a material. Nishimura, D. (n.d.). Understanding Preservation Metrics. Rochester, NY: Image Permanence Institute. Retrieved December 13, 2016, from [http://www.imagepermanenceinstitute.org/webfm\\_send/316](http://www.imagepermanenceinstitute.org/webfm_send/316)

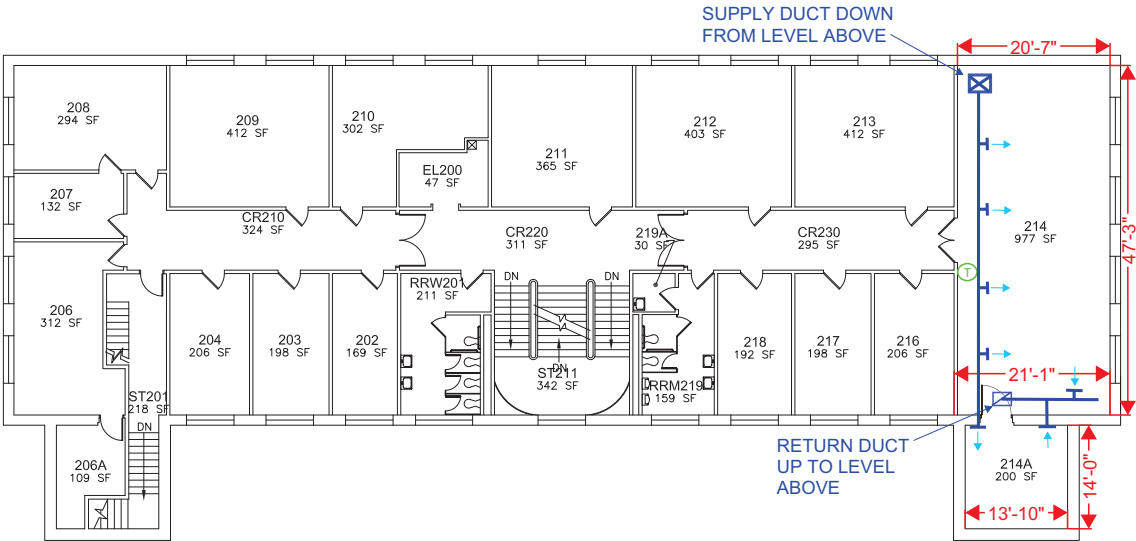
<sup>ii</sup> The Preservation Index, or PI, quantifies the rate of decay in years for a given material experiencing current temperature and relative humidity, if those conditions were to remain the same. Nishimura, D. (n.d.). Understanding Preservation Metrics. Rochester, NY: Image Permanence Institute. Retrieved December 13, 2016, from [http://www.imagepermanenceinstitute.org/webfm\\_send/316](http://www.imagepermanenceinstitute.org/webfm_send/316)



FOURTH FLOOR LEVEL



THIRD FLOOR LEVEL



SECOND FLOOR LEVEL

SCHEMATIC NOTES:

THE UNIT LOCATION AND DUCT ROUTING ARE SCHEMATIC IN NATURE WITH REGARD TO ROUTING. THEY ARE SHOWN TO CONVEY INTENT OF SYSTEM ZONING. ACTUAL DUCT ROUTING WILL BE DETERMINE LATER IN DESIGN BASED ON THOROUGH SITE INVESTIGATION AND STRUCTURAL EVALUATION FOR BUILDING WALL AND FLOOR PENETRATIONS.

A HORIZONTAL MOUNTED AHU IS SHOWN, HOWEVER A VERTICAL TYPE UNIT WILL BE EVALUATED AND CONSIDERED AS WELL, AND THE MORE DESIRABLE UNIT WILL BE CHOSEN WITH REGARD TO IMPACT ON FLOOR SPACE AND DUCT ROUTING.